Coal-to-Liquids and Advanced Low-Emissions Coal-fired Electricity Generation:

Two Very Large and Potentially Competing Demands for US Geologic CO_2 Storage Capacity before the Middle of the Century

James Dooley, Robert Dahowski, Marshall Wise, Casie Davidson
Joint Global Change Research Institute
Battelle
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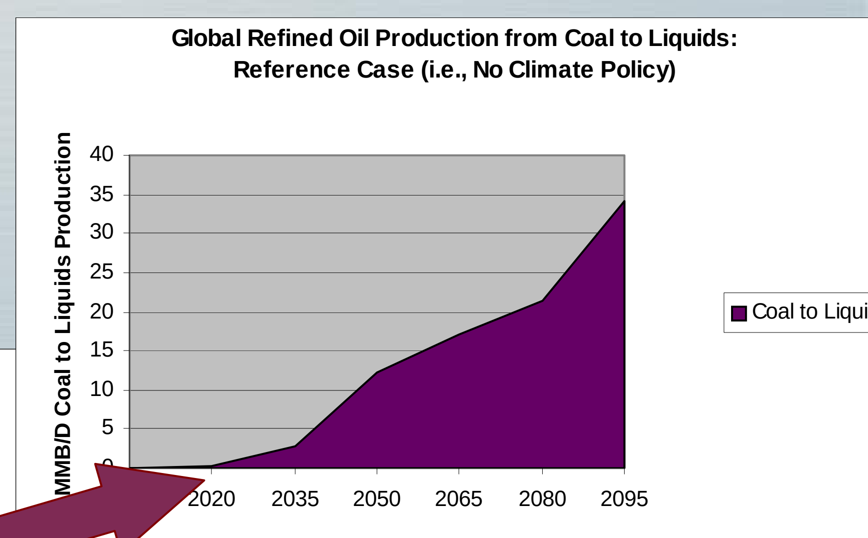
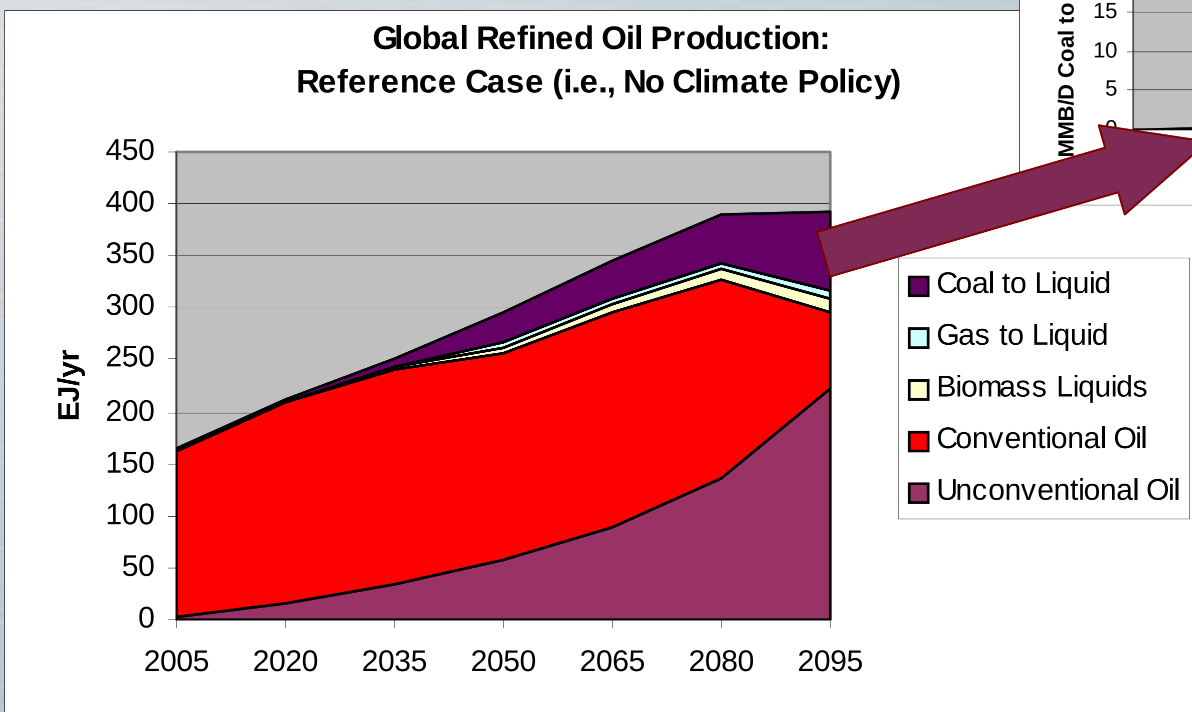
Key Points: Stabilizing Atmospheric Concentrations of GHGs Can Profoundly Impact the Competitiveness of Some Fuels

- Stabilizing atmospheric concentrations of greenhouse gases will fundamentally alter the way energy is produced and consumed across the global economy.
- The **escalating** price (or policy) signals used to trigger this transformation of the global energy system will profoundly impact which fuels are used to power the global economy.
- In particular, the competitiveness of coal-to-liquid facilities will be profoundly impacted by an altered global economic environment that stabilizes greenhouse gas concentrations.
- The degree to which and the cost at which carbon dioxide capture and storage (CCS) technologies can reduce *net CO_2 emissions* from coal-to-liquids facilities varies significantly across the various process and emissions streams produced by these facilities.
- The potential demand for geologic storage space from a sizeable (e.g., 3 MMB/D) coal-to-liquids industry in the United States could easily be on the order of tens of billions of tons of CO_2 by the middle of the century. That's nearly 10,000 times the size of current global CO_2 storage industry.

Sources of "Conventional Oil" need to be augmented to fuel a growing global economy

- In a reference case "No Climate Policy World", a global CTL industry
  - should start to emerge in the next decade and
  - would keep expanding throughout the century.





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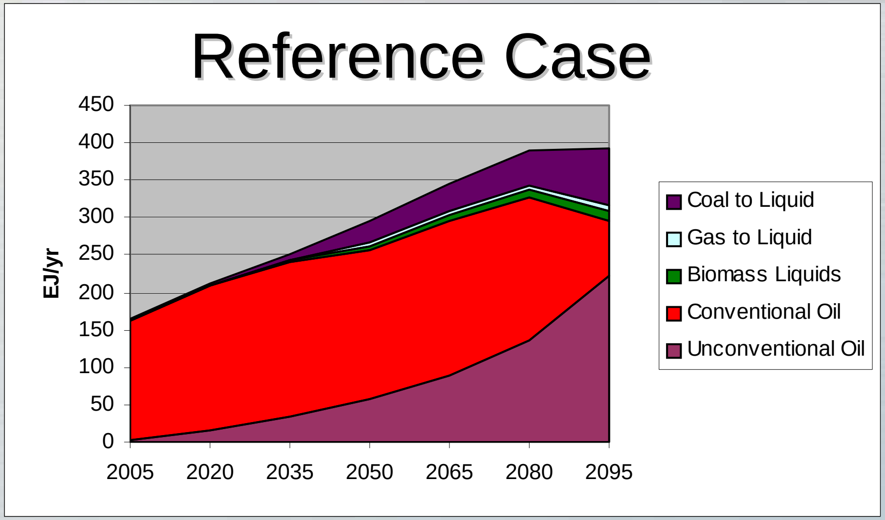
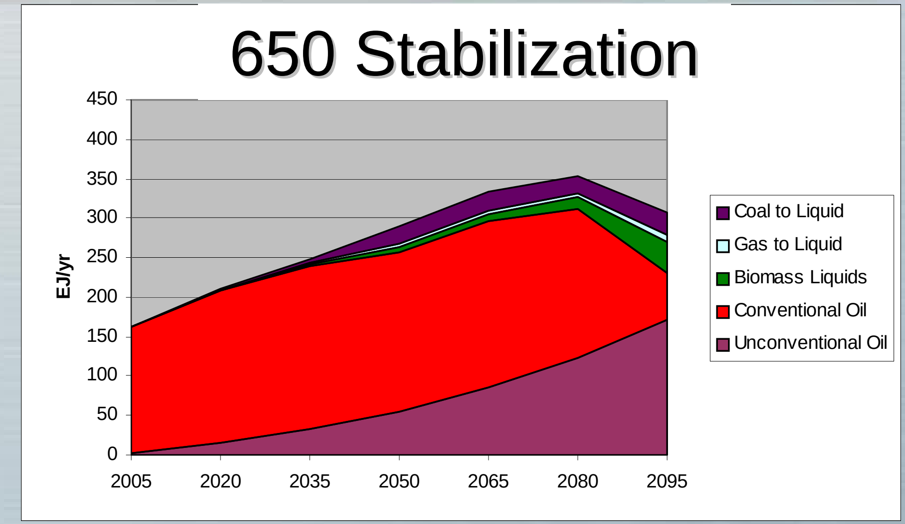
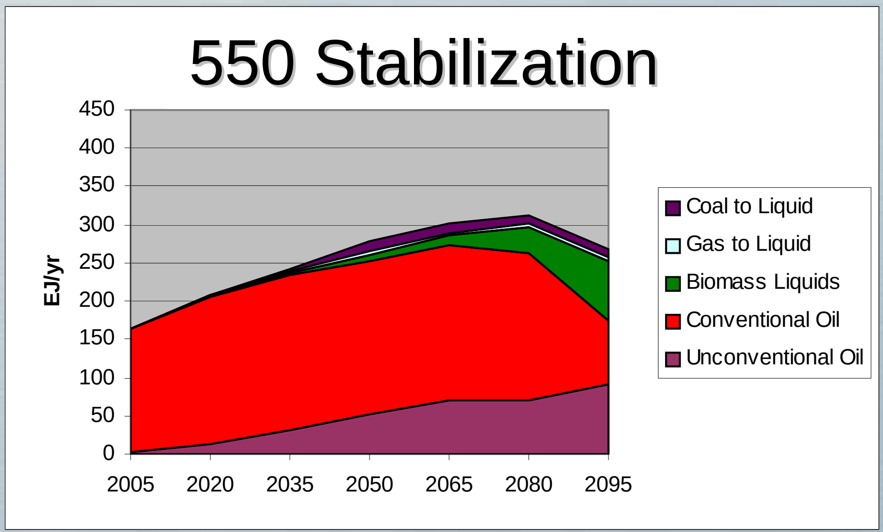
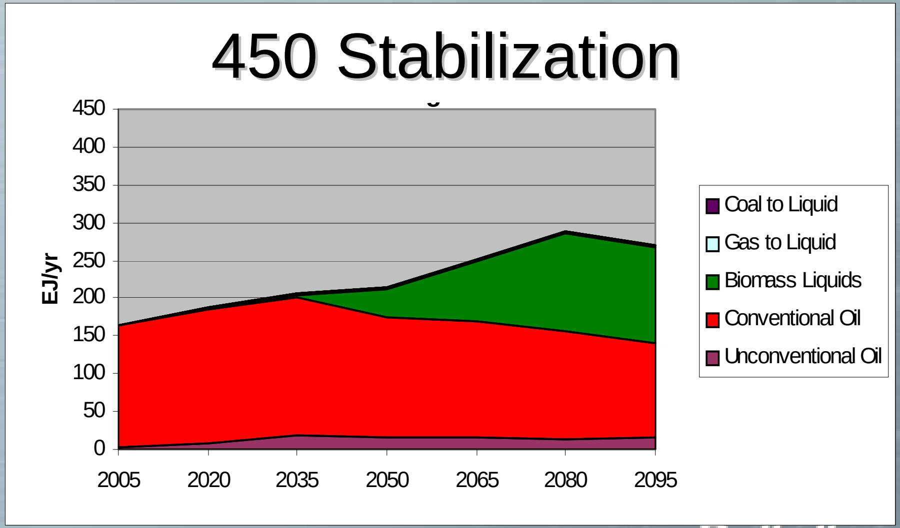
However, the economic means of augmenting this declining "Conventional Oil" production will be significantly influenced by climate policy

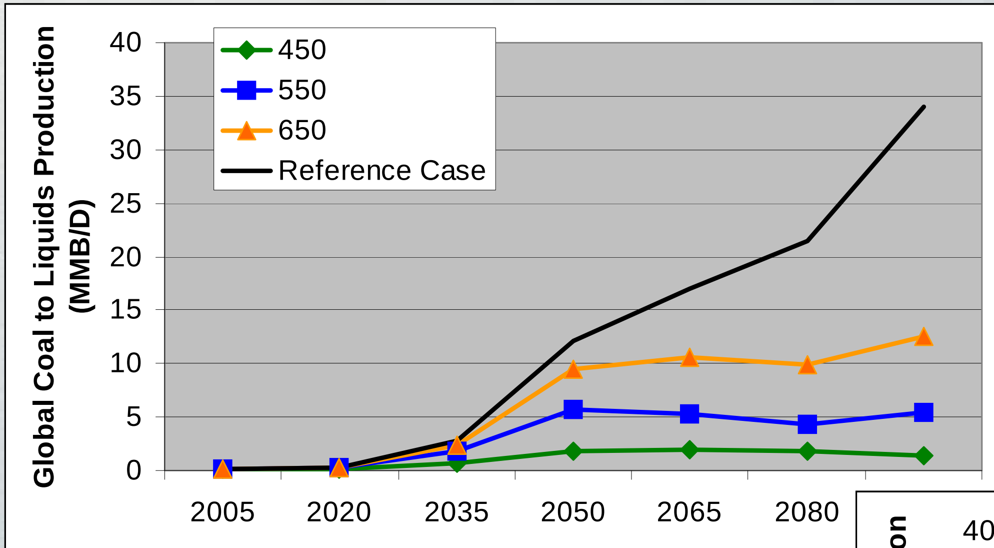






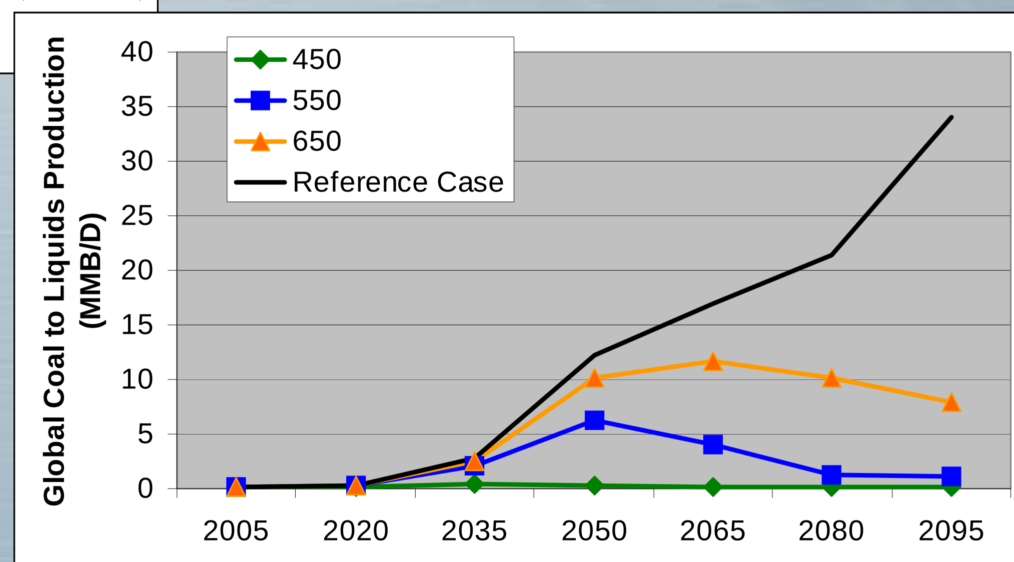


Global CTL Production Under Different Stabilization Scenarios and Availability of CCS Technologies



← Even assuming that CCS technologies are able to deploy whenever and wherever needed the economic viability of CTL production is strongly influenced by potential future climate policy.

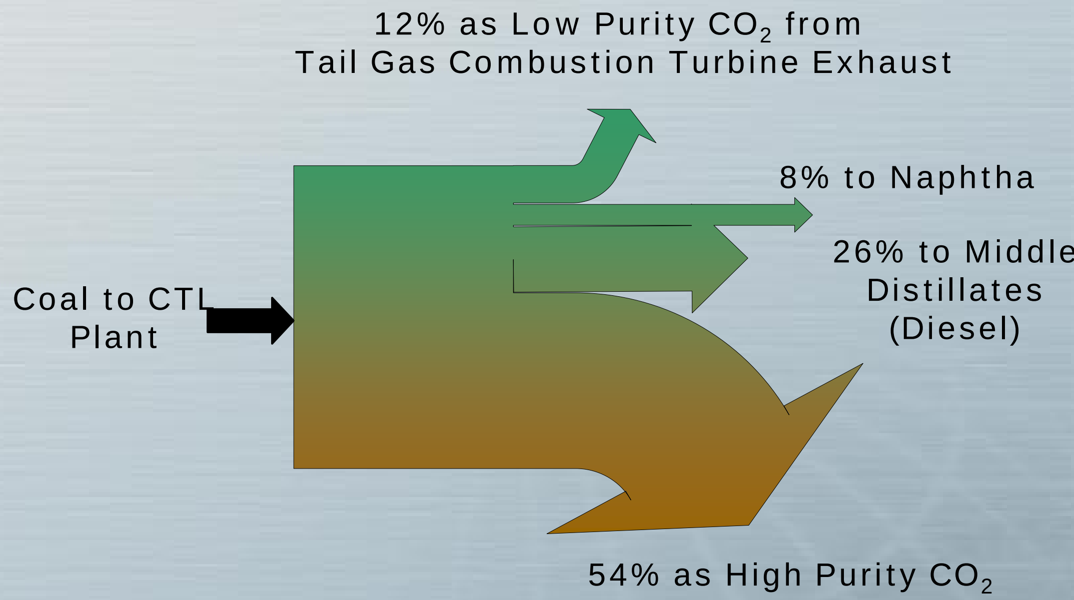
→ If CCS technologies were not available for whatever reason, it would be difficult to see a viable CTL industry in a greenhouse gas constrained world.



All CO_2 is Not Created Equal

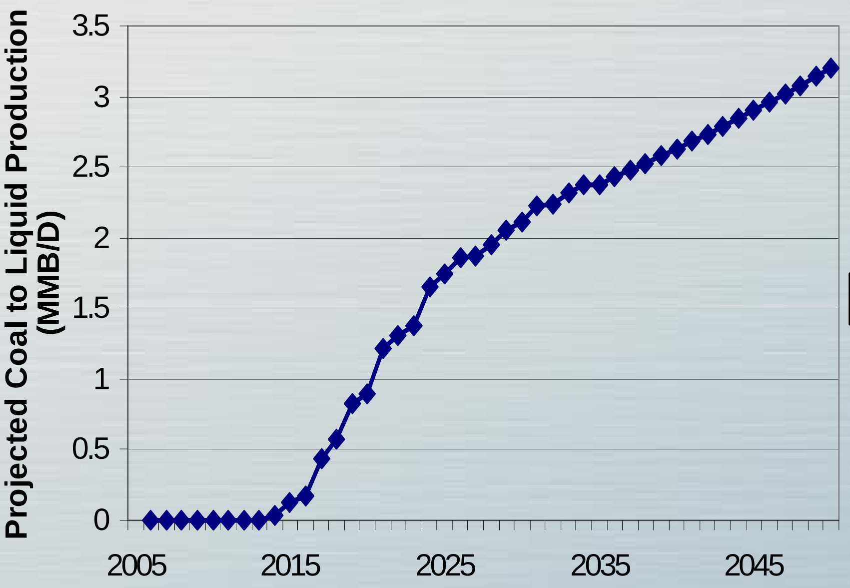
- 3 principal CO_2 streams (excluding tailpipe emissions):
  - A large high purity CO_2 stream
  - 90% of a low purity CO_2 stream which if CO_2 emissions prices are high enough could be captured
  - 10% of a low purity CO_2 stream that is unlikely to be captured unless CO_2 emissions prices are extremely high.

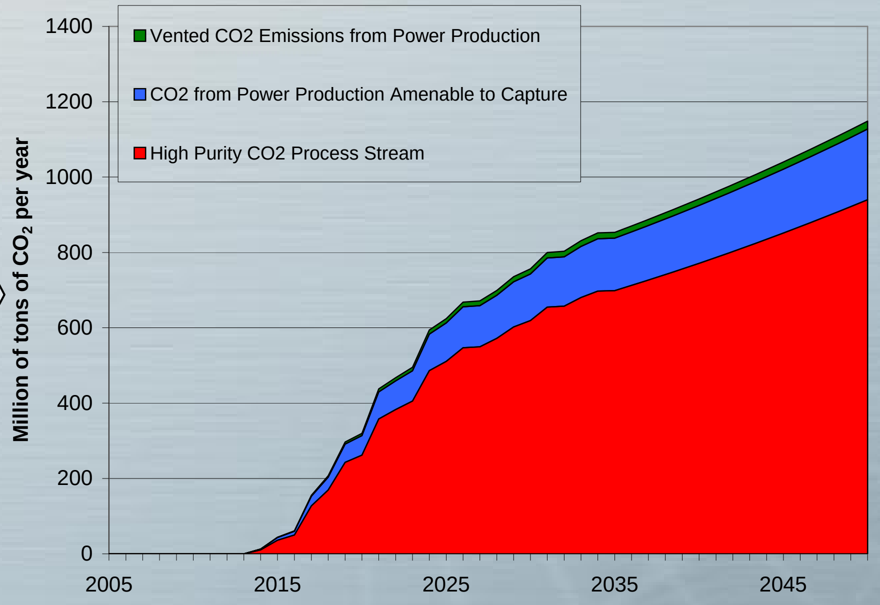
- Each stream needs to be analyzed in the context of understanding the impact of these facilities on climate change and how climate policy could impact the economic viability of these facilities.



The degree to which carbon dioxide capture and storage technologies can be used to control these three emission streams varies significantly

What would a U.S. CTL industry look like and how would climate policy impact it?





- For the purposes of this analysis, we will postulate a U.S. based CTL industry that is producing approximately 3 MMB/D of synfuel by the middle of the century.

- Before the middle of this century, this CTL industry would be responsible for creating a pool of CO_2. This "pool of CO_2" would be
  - cumulatively on the order of 25 billion tons of CO_2
  - and growing by more than 1 billion tons per year.

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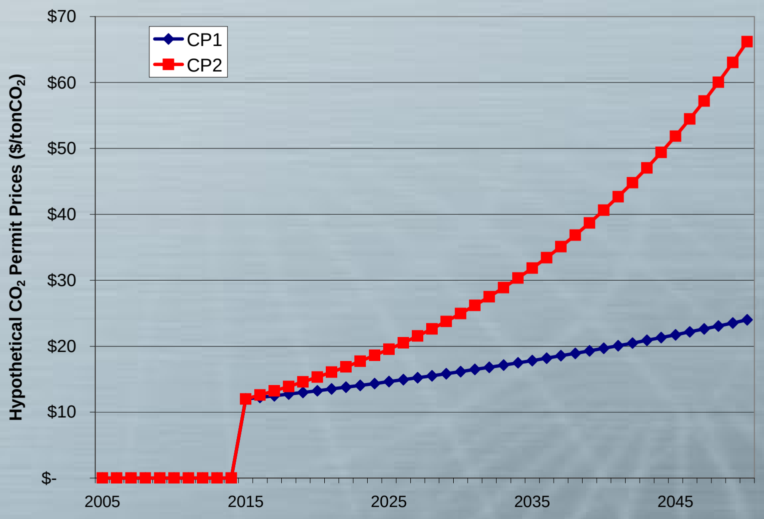
Pivotal Role for CCS

- The degree to which this pool of CO_2 contributes to climate change hinges upon which of the two potential repositories the CO_2 is stored in: the atmosphere or deep geologic reservoirs.
- Given the inherent carbon intensity of CTL production, carbon dioxide capture and storage technologies are going to be the principal means of reducing the amount of this pool of CO_2 that is deposited in the atmosphere.
- CCS technologies will be adopted when it is economic to do so (i.e., the cost of employing CCS technologies has to be less than or equal to the net effective CO_2 emission price applied to CO_2 vented to the atmosphere).

CO_2 Stream	CO_2 Produced in 2025 $MtCO_2$/yr	CO_2 Produced in 2050 $MtCO_2$/yr	CO_2 Concentration (% assumed to be capturable)	Cost of CO_2 Capture (including compression) \$/tonCO_2	Cost of CO_2 Transport, Storage and MMV \$/tCO_2
High Purity CO_2 Process Stream	511	940	High (100%)	$6	$5
CO_2 from Power Production Amenable to Capture	102	187	Low (90%)	$53	$5
Vented CO_2 Emissions from Power Production	11	21	Low (0%)	N/A	NA
Total	624	1,148			

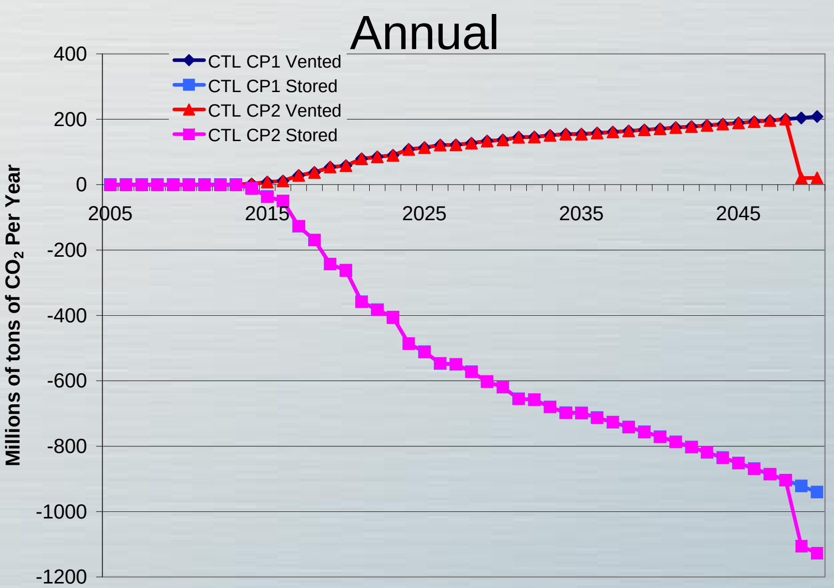
CCS Adoption in under Two *Hypothetical* Climate Policies

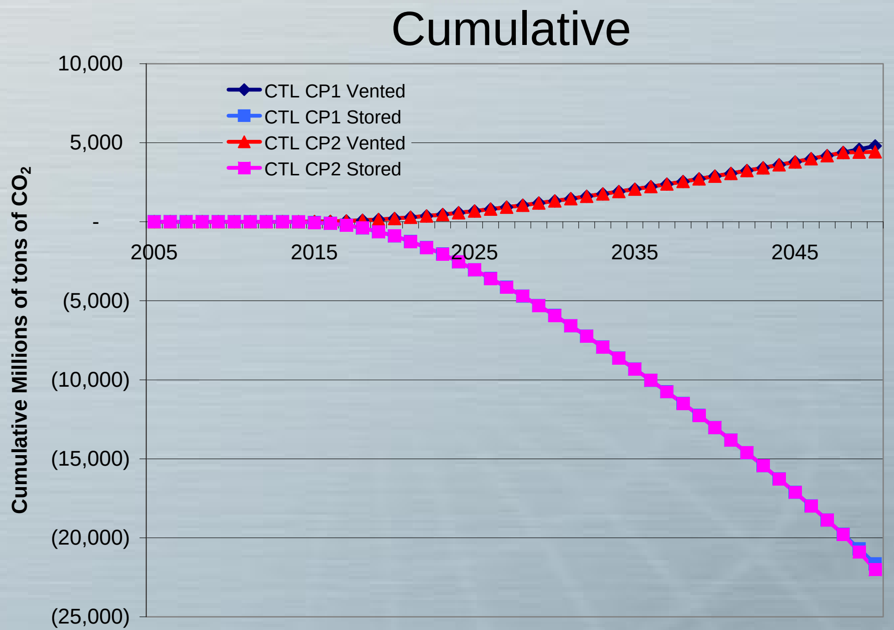
- In order to examine the potential role of CCS technologies in helping to reduce emissions from a domestic CTL, we examined two hypothetical climate policies:
  - **CP1**: the price of CO_2 emissions permits is assumed to be \$12/ton CO_2 in 2015 and to rise in real terms at 2.5% per year.
  - **CP2**: has the same starting price in 2015 (\$12/tonCO_2) but is assumed to escalate at 5% per year in real terms.



- <u>The two hypothetical climate policies adopted here are meant to be illustrative cases. They do not represent projections or predictions of what might occur in the future.</u>

Results: CO_2 Stored or Emitted to the Atmosphere under CP1 and CP2

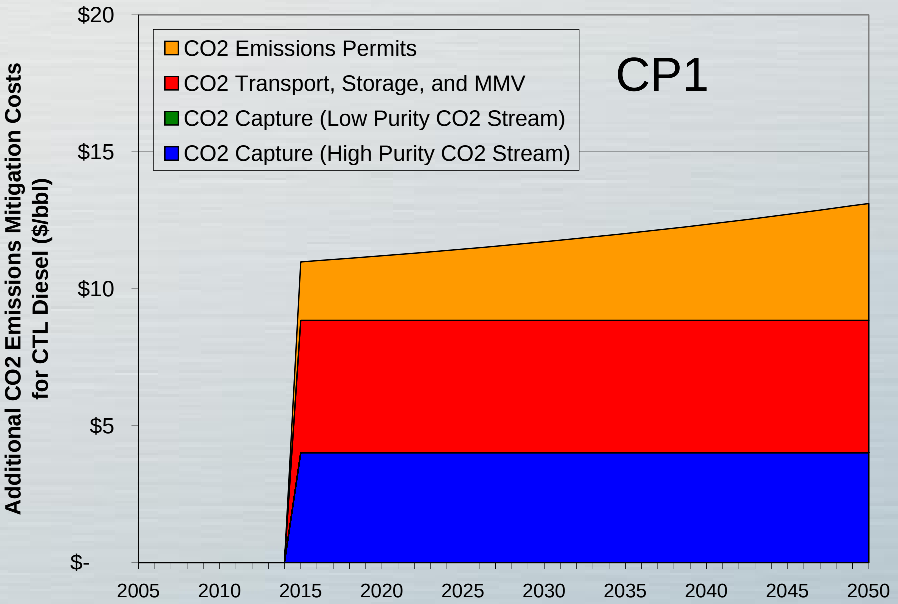


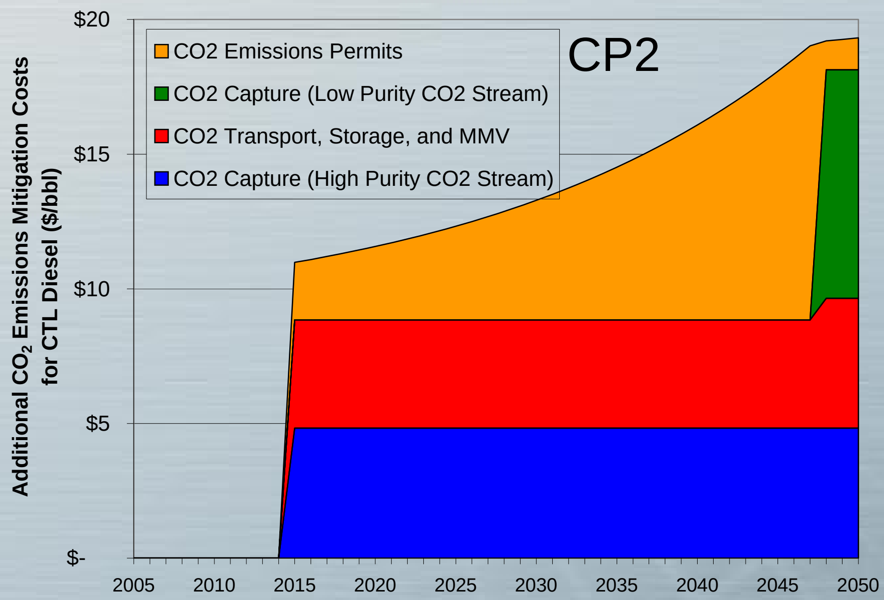


- Net annual emissions of 100 to 200 million tons of CO_2
- Purchasing emissions permits to cover these net emissions could be as much as $1-$6 billion per year
- 1 billion tons (a gigaton) of CO_2 being stored in deep geologic repositories per year is 1000 times larger than any existing commercial CCS facility

- Net cumulative emissions to the atmosphere of 5,000 $MtCO_2$ will be difficult to accommodate in a stabilization regime
- Total cost to cover net emissions via the purchase of offsets could be between $100-$160 billion in the period up to 2050
- 20,000+ $MtCO_2$ of potential storage demand

Results: Additional Climate Mitigation Costs ($/bbl) under CP1 and CP2





- CP1: the additional costs associated with complying with this hypothetical climate policy remain fairly constant in the range of $11-13/ bbl.
- These costs are increasing with time due to the need to purchase increasingly expensive emissions permits to cover emissions from the power block.

- CP2: the additional costs associated with complying with this hypothetical climate policy remain fairly constant in the range of $11-20/ bbl.
- Again, these costs are increasing with time.
  - Through 2045, the increase in these costs is being driven solely by the need to purchase increasingly expensive emissions permits to cover not-yet-economic-to-capture low purity CO_2 emissions from the power block.
  - After 2045, higher *net* cost of CO_2 capture drive these compliance costs up.

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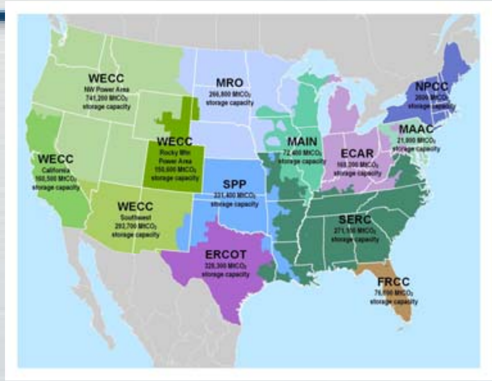
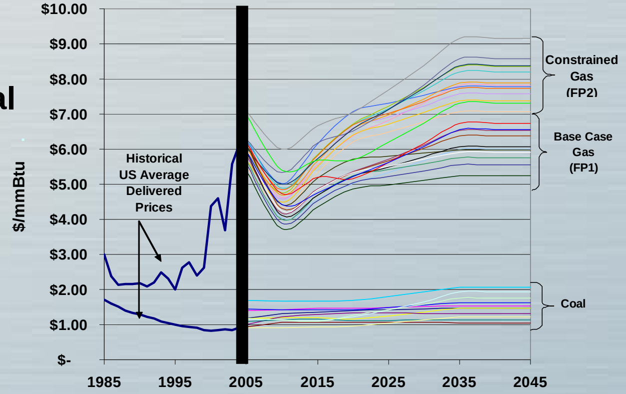
Adoption of CCS Technologies by US Electric Utility Sector in Response to Hypothetical CP1 and CP2 Climate Policies

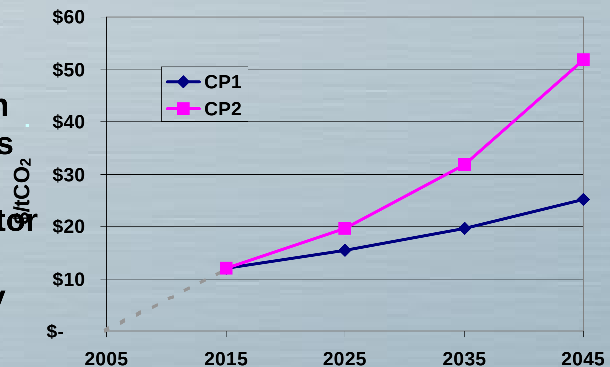
Most NERC Regions have significant CO_2 storage potential

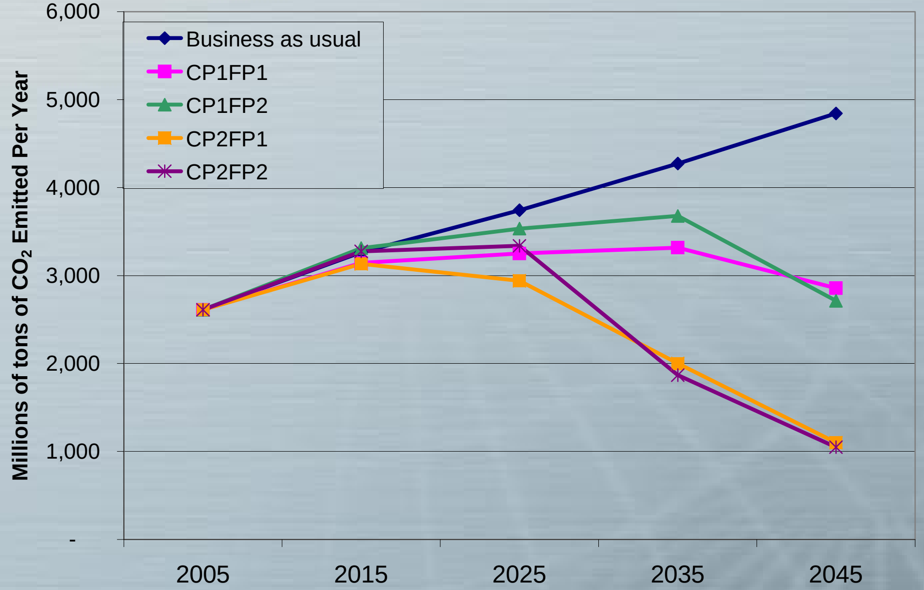


Current and projected natural gas prices have fundamentally altered dispatch economics



The possible imposition of constraints on CO_2 emissions represents an additional factor that will fundamentally alter dispatch





- 180-580 GW of coal-fired CCS capacity installed 2005-2045
- By 2045, utility sector emissions are 41-78% lower than the “business as usual” reference case

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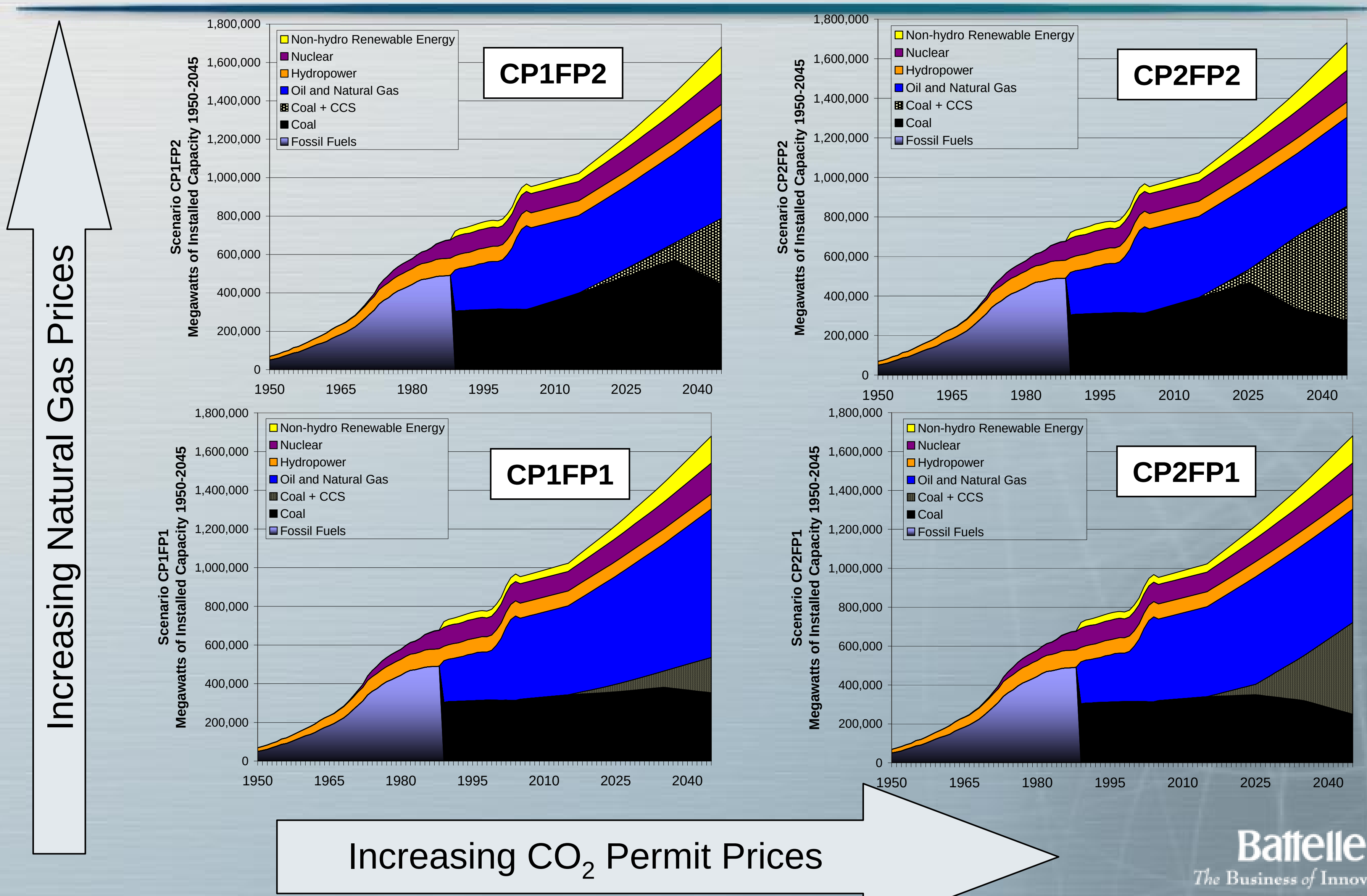
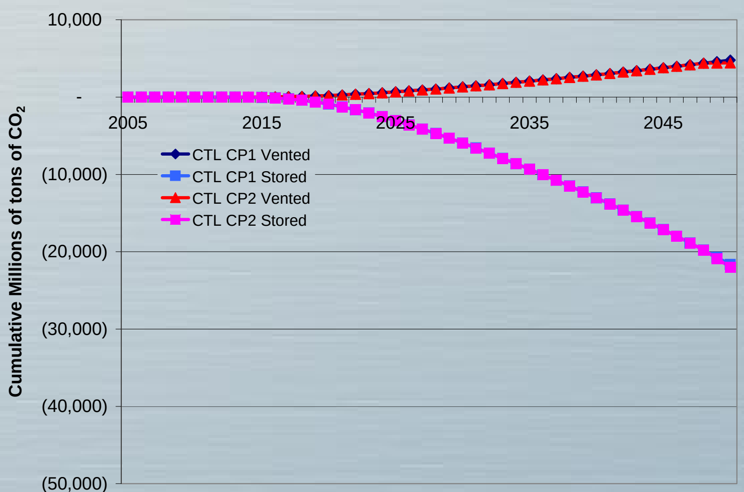
US Electricity Generation Substantially Decarbonized Across Four Scenarios

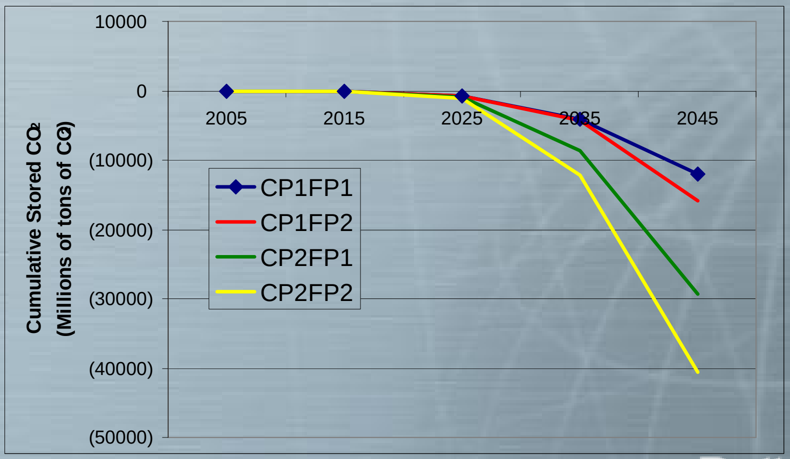


Two Very Large and Potentially Competing Demands for US Geologic CO_2 Storage Capacity before the Middle of the Century

- **CTL Production**
  - 20 billion tons of CO_2 stored in deep geologic formations
  - 5 billion tons of additional CO_2 released to the atmosphere from production process
  - Transportation (i.e., tailpipe) sector CO_2 emissions relatively unchanged
  - Modest impact on overall US dependence on foreign oil

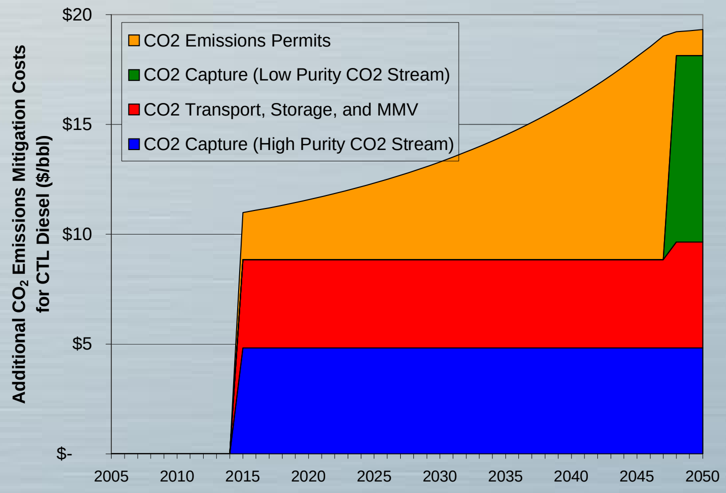
- **Electric Power Industry**
  - 12-41 billion tons of CO_2 stored in deep geologic formations
  - Utility industry emissions decrease 41-78% below reference case



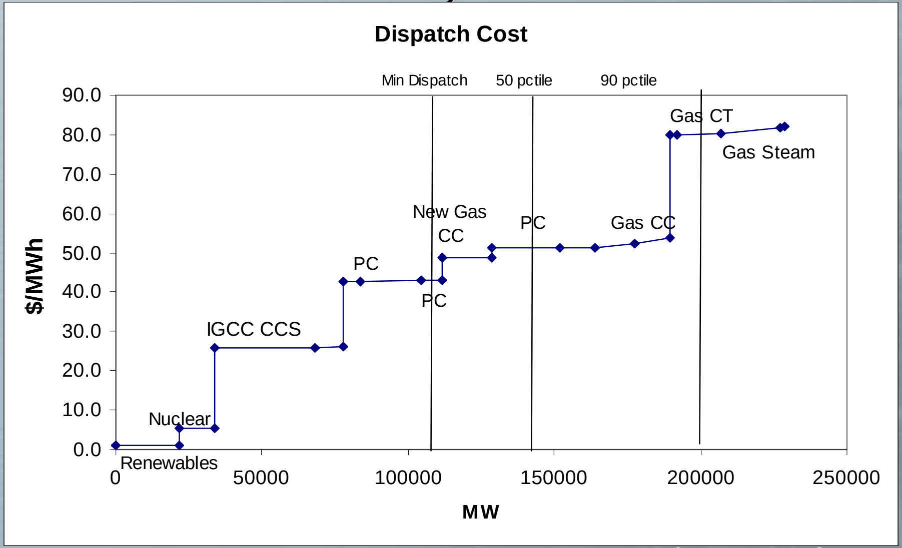


Why the profound difference in competitiveness between advanced coal fired electric generation with CCS and CTL+CCS in response to CP1 and CP2?

- **CTL Production**
  - Currently a marginally price competitive means of producing transportation fuels.
  - Additional costs resulting from the need to reduce CO_2 emissions push CTL derived fuels further away from competitiveness.



- **Coal-fired electricity production**
  - Without a carbon price coal fired electricity is already highly cost competitive means of producing electricity.
  - Additional costs resulting from the need to reduce CO_2 emissions reduces the profitability of coal plants, advanced coal fired power plants with CCS remain a cost effective means for generating baseload electricity.



- How the US electric utility sector responds to CP1 and CP2 and the subsequent adoption of CCS technologies by the electric utility industry is detailed in:
  - Wise MA, JJ Dooley, RT Dahowski, and CL Davidson (2007). "Modeling the impacts of climate policy on the deployment of carbon dioxide capture and geologic storage across electric power regions in the United States." International Journal of Greenhouse Gas Control. Volume 1, Issue 2, April 2007, Pages 261-270. doi:10.1016/S1750-5836(07)00017-5